Redesigning U.S. currency

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The first new design of United States currency in over 60 years will soon be issued. Its issuance will be the culmination of a 6-year effort to make U.S. currency more secure against widely available advanced reprographic technology. The cooperative effort was directed by the Advanced Counterfeit Deterrence (ACD) Steering Committee, with executive representives from the Federal Reserve System (FRS), U.S. Secret Service (USSS), Bureau of Engraving and Printing (BEP) and Treasury Department. A task force of technical experts from each agency carried out the necessary evaluations. The overall strategy to determine the new design and new features applied a comprehensive, synergistic approach to target each type of currency user and each type of counterfeiting. To maximize objectivity yet expedite final selection, deterrent and detection technologies were evaluated through several parallel channels. These efforts included an open request for feature samples through the *Commerce Business Daily*, in-house testing of each feature, independent evaluation by the National Research Council, in-house design development and survey of world currencies. Recommendations were submitted by the Steering Committee to the Treasury Secretary for concept approval, announced in July, 1994. Beginning in 1996, new designs will be issued by denomination approximately one per year, starting with the $100 bill. Future new design efforts will include input from the recently founded Securities Technology Institute (STI) at Johns Hopkins Applied Physics Laboratory. Input will include evaluation of existing features, development of new techniques and adversarial analysis.

keywords: counterfeit deterrence, currency features, design

1. BACKGROUND

U.S. currency is being redesigned for the first time in almost 70 years[1]. Issuance of the new design, to begin in the first quarter of 1996, is the culmination of a concerted interagency endeavor over the last six years. Attaining concensus on form and function of the new design was a critical part of the program. The notes in this new series will be substantively different from any previous U.S. currency.

When the present design was finalized in 1928, the world was a considerably different place. Currency was handled almost exclusively by people. Vending equipment and fare card machines, which accepted only coins, were in limited use. Large volumes of cash were generally sorted by hand; getting cash meant making a trip to the bank. In 1928, monochrome photography was the norm; color photography was just being born. Typewriters were manual, so generating an original document was tedious by today's standards. Mistakes had to be hand corrected on the original as well as on any carbon copies. Xerographic reproduction had not been invented; making copies of documents was a laborious process, even in black and white, much less in color.

Today this has all changed. Vending machines dispense everything from popcorn to fare cards to coins. Retail operations have sophisticated sorting equipment on site. Federal Reserve Banks run state-of-the-art high speed sorting equipment around the clock. Ubiquitous automated teller machines dispense cash on demand. Color photographs can be developed on site at grocery stores and color copies of documents can be output at the push of a button. Documents are generated on computers linked to high-quality printers, which are increasingly capable of color output. Data can be manipulated digitally in the computer at will. Mistakes are corrected with the flick of a finger or the click of a mouse.

These factors haved changed the function of currency. To function into the 21st century, U.S. currency had to be adapted to the current technology, to address all types of usage and to hinder all types of abuse. Thus the new design is intended to enhance the security of the currency against all types of reprographic art and to facilitate authentication of the notes for both humans and machines.

1.1. Advanced Counterfeit Deterrence Steering Committee

The first concerns about advances in reprographic technology arose in the late 1970's when copier manufacturers began serious devlopment of color copying equipment. The main concern was that the new equipment would provide the opportunity for the general public to counterfeit U.S. currency. This "casual counterfeiting," would be in direct contrast to professional counterfeiting, typically carried out by criminals using specialized skills and equipment. While the USSS is very effective at tracing and apprehending the

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traditional counterfeiter, this new type would be much more elusive and difficult for them to control. The threat of this problem arising from the development in color copying and advanced reprographics in general led to the establishment in 1982 of theACD Steering Committee.

The ACD Steering Committee is a permanent ad hoc interagency policy group comprising senior level executives from the Treasury Department, the BEP, the USSS, and the Federal Reserve. Since its establishment, this body has been addressing issues related to the counterfeiting of U.S. currency and its prevention. Any changes to the currency are first approved by the ACD Steering Committee before submission to the Secretary of the Treasury for final authorization.

Although the level of counterfeit U.S. currency remains low (less than \$100,000,000 passed worldwide[2] during fiscal year 1995 vs. \$380,000,000,000 estimated in circulation), no counterfeiting level is considered acceptable. In addition, the nature of the threat changes with the introduction of office and personal reprographic equipment. Now, instead of requiring the use of large, expensive, specialized equipment, counterfeiting can be carried out casually using push-button technology. The availability of high-resolution professional and desktop scanners, computerized graphics, sophisticated color output software and hardware and direct-to-plate equipment in mainstream markets has increased both the accessibility of the technology to counterfeit and the competence of the outcome.

1.2 Early efforts to redesign U.S. currency

The ACD Steering Committee began the first efforts to redesign U.S. currency soon after its establishment. Although many options to enhance the security of the currency against this emerging technology were considered[3,4,5,6,7] those features which were ultimately implemented were restricted for political reasons to ones which would not significantly change the appearance of the notes. With this constraint, limited but effective enhancements to the security of the currency were made beginning in 1990. To the currency paper itself was added an embedded polyester security thread. This thread is visible in transmitted light, but not seen in the reflected light used in copying equipment. Around the portraits, a fine line (~150microns) of microprinting was engraved into the design. This level of detail was beyond the resolution of contemporary copying equipment. These two features now appear in all higher denomination notes (\$100, \$50, \$20, \$10 and \$5 notes).

Though highly effective against current reprographic equipment, these enhancements were considered only a first step in addressing the overall issue of counterfeiting. The copiers and printers now being placed have resolutions in the 600-720 dpi range for black and white, usually with lower ranges (300-400dpi) for color output. As the resolution and color gamut of the equipment increases, the effectiveness of some features, such as intaglio microprinting and even color itself, will lose effectiveness. Therefore, in 1990, before the first notes of the enhanced series were even issued, the ACD Steering Committee began a new effort to redesign U.S. currency. This time, no restrictions were place on changing the way the currency would look. The result of the effort are shown in Figure 1and described in the following section.

2. NEW FEATURES

The main features included in the new currency design are the following:
Larger, off-center portrait. Making the intaglio portrait larger and off-setting it from the center improves its intrinsic security by enhancing its recognizability and by removing it from the most heavily folded area of the note.
Registered portrait watermark. The watermark, registered to fit within the same space on each note, is a rendition of the engraved portrait to readily identify the paper with the printed image and make color-copying, bleaching and raising of notes less effective.
Color-shifting ink. The green-to-black color-shifing ink is difficult to simulate or reproduce using both conventional and advanced technology, and provides a highly visual means of authentication for the general public.
Enhanced Security Thread. The security thread currently in use in U.S. currency, an embedded, microprinted thread which can be seen only when held to a light, has been enhanced to emit red under ultraviolet radiation, aiding both automated and assisted visual verification.
Intaglio Microprinting. Intaglio microprinting, at a resolution of 6-7 thousands of an inch, is again included as a cost-effective feature against the current generation of most office copiers, which have resolutions below 600 dpi.
Fine-Line Patterns: Concentric fine-line interference patterns used to induce irregularities in copied images augment the effectiveness of traditional intaglio printing against both traditional and advanced reproduction methods.

The features described above were chosen using the approach described in the section following Figure 1.

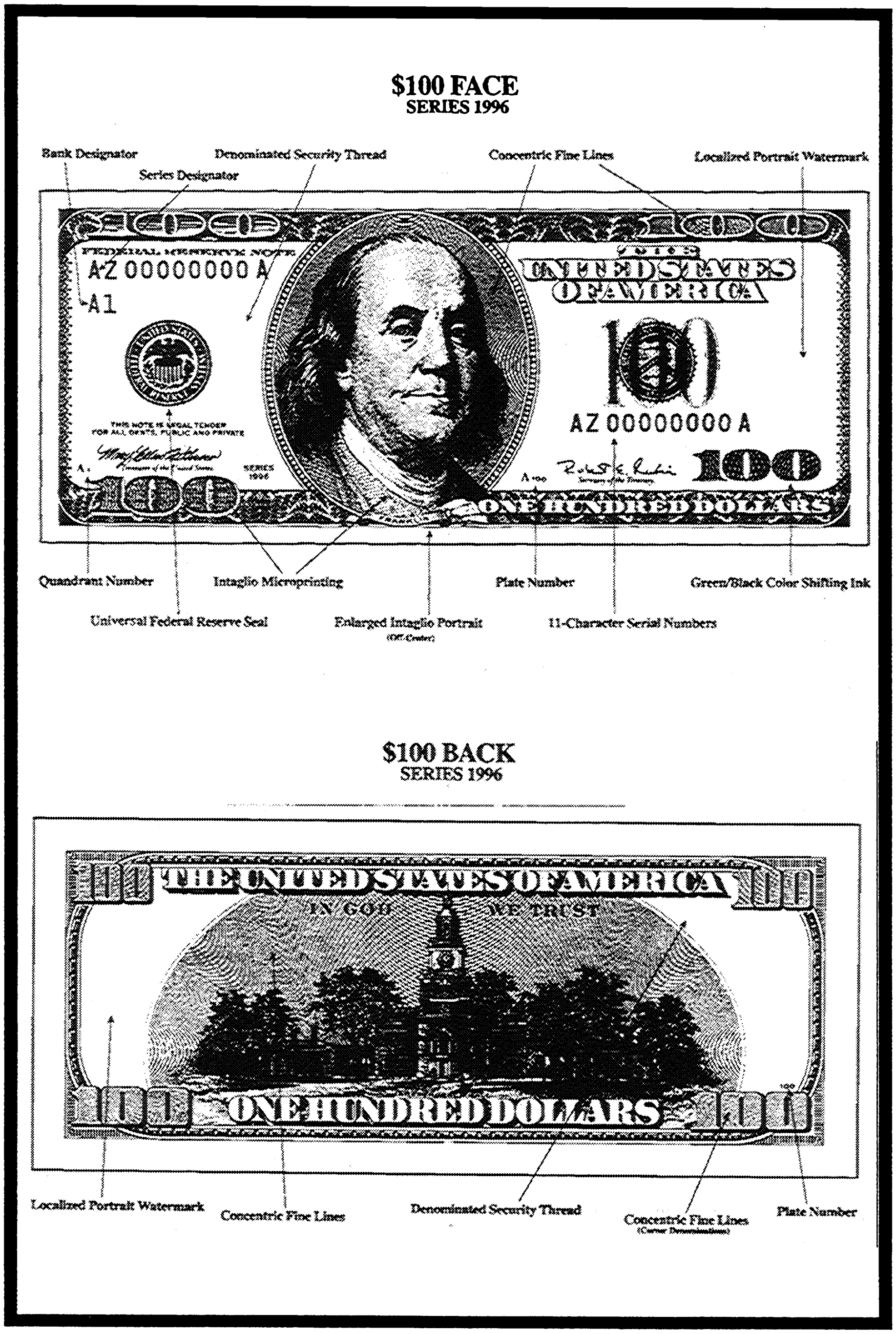

Figure 1. Series 1996 $100 note design and features

3. APPROACH

The features included in the new 1996 design series were selected from a broad field of options through an orchestrated process involving government, private and independent participants. The main tenets of the project were the following:

1) The new design would be implemented solely to the enhance the security of U.S. currency. This restriction avoids lengthy discussions on the aesthetics of individual design or feature elements, such as portrait and vignette subjects or arbitrary colors.
2) The main emphasis would be on overt features for use by the general public. The public serves as the first line of defense against the spread of counterfeits, both by refusing them in the first place and by identifying them closer to their origination point, where the trail is still warm.
3) The study was to be as broad as possible, to survey the international market for potential features. Any restrictions on types of features were to arise naturally out of the evaluation process not for political reasons.
4) A parallel but independent study of counterfeit deterrence features was to be carried out by the National Research Council (NRC). This study would extend the earlier work by the NRC in which the thread and microprinting were recommended as effective features to use in U.S. currency.
5) The engraved design would be developed simultaneously with the feature studies and the layout adapted as features were identified. This schedule was designed to shorten the overall time to implementation of the new series.
6) The new design must not undermine the crucial element of public confidence in United States currency. The new currency must continue to serve as a de facto world currency.

3.1 New Currency Design Task Force

Late in 1990, to execute the tenets of the new program, the ACD Steering Committee established the New Currency Design (NCD) Task Force, with technical representation from each of its member agencies. This group was charged with developing short-, intermediate- and long-term plans to respond to security threats to U.S. currency. The short-term plan was quickly agreed to be the continuation of the implementation of the features included in the Series 1990 $100 notes in the lower denominations. Thus the main focus of the Task Force would be on intermediate- and long-term plans.

Once the short-term plan was settled, the activities of the Task Force focussed on developing a philosophy for longer term design development. According to the philosophy they adopted, there is no perfect "counterfeit-proof" design. Anything that the BEP can produce, someone else can duplicate or simulate. The highest security will result from a synergistic synthesis of a multilevel range of features directed at each of the various users and technological threats. The goal of the design would be to make the note increasingly difficult for counterfeiters to duplicate and increasingly easy for legitimate users to authenticate.

A further aspect of the philosophy is that the effort must be regarded as preemptive because of the time lag between design conception, implementation and predominance in circulation. Although future technology can be anticipated to some extent, it must be continually reviewed and protected against. From now on, changes will have to be made to U.S. currency on a regular basis in anticipation of changing threats from advances and shifts in technology.

Several factors affected the design approach of the NCD Task Force and imposed certain constraints if a timely issue of the new currency was to occur. First, both designs must inevitably co-circulate during the conversion from old to new design currency, so both people and machines must be able to handle both designs at the same time. In addition, the new currency should retain the overall look and feel of U.S. currency to provide continuity and aid recognition internationally, since the majority of U.S. currency is held abroad. A third aspect of the approach is that security features in the current design, such as the thread and microprinting, should be built upon rather than discarded, thus enhancing continuity. The goal of timely issue further obviated any discussions on changing the portrait subjects -- any changes made to the currency were to be for security purposes rather than aesthetic or political. Likewise, without an urgently compelling security reason, there should be no changes in the size of currency and all denominations should remain the same size. Changing the size of the currency would force a large segment of the U.S. population, including the Federal Reserve and BEP, into an expensive changeover to flexible-size equipment for processing, storing and handling the two currency designs.

In close cooperation with the BEP, the NCD Task Force evaluated over 135 individual features from more than 35 companies for area of effectiveness, security, intelligibility, production factors and complexity. These factors are explained in more detail in the companion paper Evaluation of Security Features for New U.S. Currency. Through international contacts and direct examination, the Task Force also carried out an informal survey of modern currencies, to learn which features were most effective and what sorts of drawbacks might be associated with each.

When all of the development components were completed, results from each were evaluated by the NCD Task Force and compiled as a final but generalized set of recommendations. For instance, the Task Force recommended the use of a machine-detectable thread, but did not specify how it should be detectable. Also recommended was a color-shifting ink, but not the color pair to be used. In January 1994, these general recommendations were presented to the ACD Steering Committee for their approval. A schematic design layout was developed and tailored to accommodate the recommended features. The combined schematic design and generalized features were then presented to the Secretary of the Treasury with the understanding that some features may be eliminated during pre-production testing. On July 14, 1994, the Secretary approved the design concept and recommendations, which were subsequently presented to Congress and publicly announced that same day.

The Secretary's approval authorized the BEP to proceed with engraving, plate manufacture, procurement of production materials and pre-production testing. Over the next year a series of scale-up tests were carried out.

3.2 National Research Council (NRC) Study

Under the direction of the NCD Task Force, BEP contracted with the NRC to study the effectiveness of available counterfeit deterrence features for use in United States currency. This study includes a review of the threats posed by current and developing technologies and an analysis of the counterfeit deterrent methodologies available to thwart these threats. The NCD Task Force was represented at all NRC working meetings, both to serve as resources and to track the progress of their evaluations. The final report[8] was published in December 1993 as "Counterfeit Deterrent Features for the Next-Generation Currency Design" and its findings were incorporated into the final design recommendations of the Task Force to the ACD Steering Committee in January 1994. This report, in keeping with the design approach of the NCD Task Force, recommends features for use in the short-, intermediate- and long-term time frames. Many of the reports recommendations, such as the color-shifting ink, enhanced security thread, alias-generating line structures and localized watermark, have been adopted in the new design.

During the course of the Committee's studies of counterfeit deterrent features, the related topic of features for use by visually impaired or blind people was raised frequently. Since this type of feature had not been addressed in any other context, the contract with NRC was extended to deal specifically with this issue, to identify features useful to blind or visually impaired segments of the population. The recommendations of this study[9] included the use of larger, bolder numerals for denominating the notes. This recommendation will likely be incorporated into the new series of notes. Other recommendations will be studied further for possible use in future designs.

The use of the NRC, which was established by President Lincoln to advise the government on technical issues, has not only provided practical input to the design effort but has also independently validated design and feature decisions made by the government. This input and support have proved invaluable in attaining concensus to proceed with the new design.

3.3. Design Development

The graphic design development for the new series of notes was carried out in tandem with the feature selection. Ideally, the form would follow function -- the design would be developed to work synergistically with the elements it would include. However, for this project, the targeted development time was too short to allow this natural schedule. Consequently, the design series was developed first as a concept, with details added as the types of features which would be included became clearer. Initial development was carried out using the $20 denomination as an prototype since a new portrait had already been engraved for earlier studies. This e

To choose a concept, an iterative process was used. First, all the BEP banknote designers were asked to submit schematic designs representing a wide range of concepts, from traditional to contemporary. These concepts were reviewed first by BEP personnel, then the NCD Task Force, the ACD Steering Committee and finally the Secretary's office at the Main Treasury. Three of the design concepts, representing various degrees of departure from the current design, were selected for further consideration and drawn in more detail.

LIMITED CHANGE. Maintain as much of the current design as possible and add new features such as planchettes, enhanced fibers, thread and intaglio inks, in the available space.

MODERATE CHANGE. Retain some existing design elements but change the layout to provide areas for the inclusion of new features such as watermarks or other graphic or optical features.

NEW DESIGN. Redesign the note image and layout completely to incorporate enhanced intaglio portraits and other visual features and maximize inclusion of new security elements.

From among these three options, one was chosen to develop for presentation to the Secretary of the Treasury, who holds discretion for the design. The prototype developed from this concept was used to test various features and substrates under consideration, to maximize the synergy of the design and the features in a preliminary way. Some modifications were then made to this design to optimize the options for feature locations; other changes were made to enhance continuity with the current design. Ultimately, a layout was developed which would be flexible in accommodating the inclusion of both new and traditional features. This concept, which would be first executed for the $100 note, was presented to Secretary of the Treasury on July 14, 1994 and announced in a press conference. The concept featured a larger, offset portrait, space for a watermark and a series of features to be tested for production feasibility. Implicit in the concept approval was the likelihood that not all approved features would survive production testing.

Over the next 15 months, the design for the new $100 was engraved, proofed, reproduced into plates and tested with the specified features. Although some adjustments in the engraved details were made during this period in response to test results, the design was finalized when the Secretary of the Treasury authorized its production in September, 1996.

3.4 Market Survey: Commerce Business Daily (*CBD*) Solicitation

Early in the new currency design program, an open solicitation for counterfeit deterrent features was published in the *Commerce Business Daily*, the government's organ for announcing all contractual transactions. Although BEP was already aware of many types of counterfeit deterrent features, publication of the solicitation served two purposes. First, it was intended to elicit responses from new sources of innovative products not already known to the BEP. Second, the publication of the solicitation provided a purchasing mechanism for procuring materials for laboratory and scale-up testing. Under the solicitation, vendors of counterfeit deterrent features were asked to submit small, generic samples and cost information for the purchase of larger quantities. In all, over 135 features from more than 35 separate vendors were received. Each feature was evaluated subjectively by the NCD Task Force, the NRC and the BEP design team. Of the features reviewed, approximately one-third were selected for further testing and obtained in larger quantities.

These features were subjected various types of tests, depending on the nature of the feature. Where feasible, small production tests were carried out and the samples subjected to full durability testing, which normally includes laundry, chemical rub, chemical soak and crumple tests. For example, the color-shifting inks were first hand printed using non-specific dies and non-distinctive currency paper. After larger samples had been purchased, limited press trials with $20 plates were carried out, followed by full-durability testing. Holograms and diffraction-based features, which were purchased already affixed to a substrate, were intaglio printed when possible and subjected to a durability test developed just for the purpose. In this test, actually a modified soiling test, the exemplars are tumbled in an actual cement mixer with clean rags and blocks for a set time to assess robustness against normal wear. This test was developed to suppliment conventional tests, which were created specifically to test ink adhesion.

4. SUMMARY

The U.S., through the interagency ACD Steering Committee, adopted a preemptive, multiple track strategy to develop a new design for its currency. The parallel-course strategy was designed to expedite the development and issuance of the new design without short-circuiting the necessary evaluations and test phases. This was accomplished in several ways. First, certain guidelines were established both to ensure continuity from the old to the new design and to subvert lengthy, politically-sensitive discussions concerning design content. In general, the new design would build on the old design, using new renditions of the same historical subjects. Features to be considered should be sufficiently developed technically for near-future use. Second, the effort was to be coordinated through the NCD Task Force, which would collect and synthesize information received through the parallel tracks. In addition, the Task Force would survey features and designs used in modern currencies throughout the world. Third, the BEP, focussing on production and durability issues, would carry out an internal study of features to be received under an open solicitation published in the *Commerce Business Daily*. Fourth, a committee of experts assembled by the NRC would review any features under consideration, plus originate innovative techniques. Fifth, BEP designers would develop a range of design options with sufficient inherent flexibility to accommodate a variety of new features. Once these parallel efforts were completed, the results would be synthesized into a design concept with a synergistic layering of features. After the concept approval by the Secretary of the Treasury, the design and features would be tailored for the $100 note and tested for production readiness. By fall of 1995, the new design $100 notes would be ready for production, with issuance to begin in the first quarter of 1996.

New designs for the lower denominations will be issued in descending order at one-year intervals.

The future strategy for protecting U.S. currency is based on the premise that preemptive changes will be required on a regular basis as technology changes. Before all the 1996 series notes are issued, studies to determine the subsequent range of features will already be under way. To assist in the studies, the BEP has contracted with the Johns Hopkins Applied Physics Laboratories to establish a Securities Technology Institute (STI). This institute will not only provide independent and scholarly analyses of existing technology, but also develop new techniques for preventing and identifying counterfeiting. Working closely with the BEP, the STI will provide ongoing input to the government's counterfeit deterrence program and help ensure the continued strength of U.S. currency.

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